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AD-P004 270	Stresses in Situ Generating by Bulldozers
AD-P004 271	Finite Element Analysis of Ground Deformation Beneath Moving Track Loads
AD-P004 2[illegible]	A Rig for Testing the Soft Soil Performance of Track Systems
AD-P004 [illegible]	Die Abhaengigkeit der Bodentragfaehigkeit und der Zugkraft von der Abstandgroesse der Bodenplatten (The Dependence of Soil Bearing Capacity and Drawbar Pull on the Spacing between Track Plates)
AD-P004 274	The Dynamic Interaction between Track and Soil
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AD-P004 282	Characteristics of Fram Field Profiles as Sources of Tractor Vibration

ANALYSIS OF GROUND PRESSURE DISTRIBUTION BENEATH TRACKED MODEL WITH RESPECT TO EXTERNAL LOADING

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INTRODUCTION

This paper is a continuation of the investigation,results of which were presented at the last Conference ISTVS in Calgary in 1981 /Traction Investigation of a Tracked Vehicle Model/.
The results obtained then permitted to draw certain conclusions, however the necessity of rearrangement concerned with the test model and the frame of conducted investigation appeared simultaneously.
New research aimed at settling the effect of changes of the centre of gravity /C.G./ on tractive efforts and on distribution of ground pressure beneath the track /i.e. MMP, NGP/. The location of C.G. varied according to the changes of external loadings.
The measurement of the drawbar pull and the distribution of pressure between track and soil layer were carried out in the model scale.

THE TEST-STAND

The model of the tracked self-propelled vehicle running in the mobil soil bin was the mechanical part of the test apparatus. The model and the soil bin were being described in the paper which was presented at the last Conference[1].
The system of registration of the drawbar pull underwent a changes. The vehicle model was connected with the immovable socle through an octogonal dynamometer designed according to [2]. The measuring system of drawbar pull had better sensivity and linearity than previous one /Fig. 1/
The rigid steel plate enabling front loading of the model /with the aid of bob/ was mounted right over the front wheel /Fig. 2/.

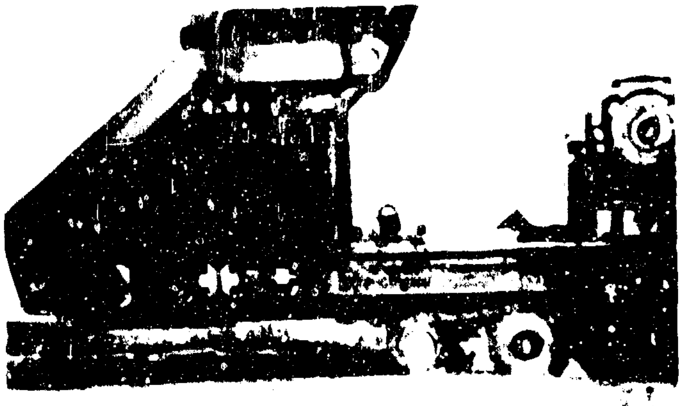


Fig. 1

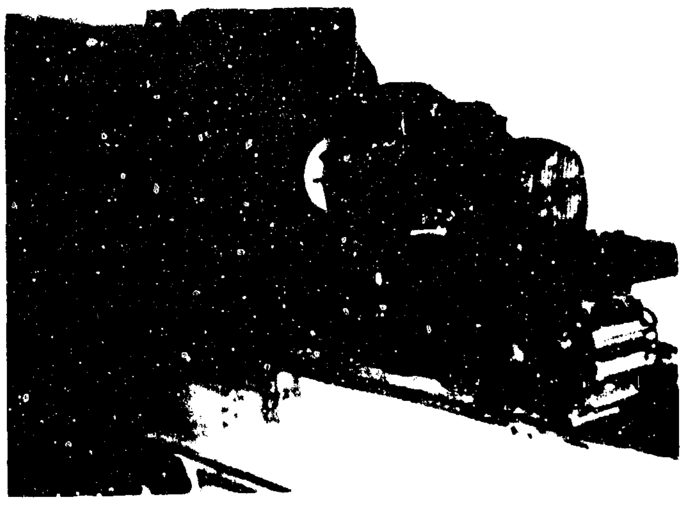


Fig. 2

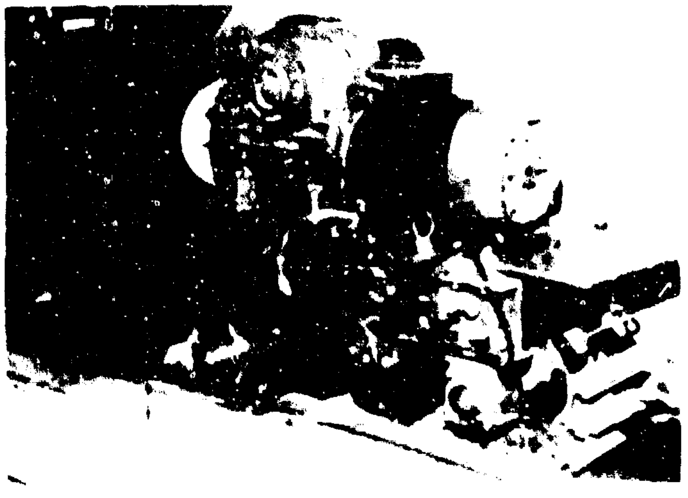


Fig. 4

PREPARATION OF THE SOIL

The soil prepared for measurements had specified mechanical constitution due to uniform mixing and humidification so that it possessed homogeneous structure,humidity and density in the whole bin.
Humidity of the soil was checked every day before beginning and after completion of the experiments.
Before each test the soil was mixed,levellized and compacted by means of mechanical compactor.
All the tests were carried out on the clayey sand.
The physical soil properties and the grain size distribution are shown in Table 1 and Fig. 3 respectively.

Table 1. Physical properties of the soil

wet density /kN/m^3/	26,1
average water content /%/	9,0
cohesion /kPa/	10,0
angle of internal friction	29,0
bulk density /kN/m^3/	16,0

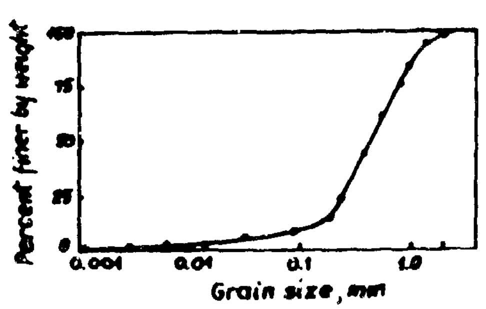


Fig. 3. Grain size distribution of tested soil.

TRACTIVE MEASUREMENTS

The disposable drawbar pull and the machine loading coming from the soil /when the track was rolling/ were registered during the tests. The tests were carried out for the value of slippage s=20% and s=100% /what means loosening the machine adherence with soil/.

In comparison with previous investigation there were increase of slippage value from s=8,4% to s=20%. It was so, because the tendency to the lateral tilt occured when the slippage value was s=8,4%. It mainly took place after 2,0 or 2,5 m of riding. When slippage value was 20% model was not disposed to tilt itself.

The location of C.G. was varied in each serie of measurements.

The simulated external loading of the model was obtained by means of additional masses fastened down to the model at different places.

The following drafts of loading were separated:

a/	an additional mass	228 N	/8,8%	mass of the model/	-Fig. 4
b/	"	319 N	/12,3%	" /	-Fig. 5
c/	"	547 N	/21,0%	" /	-Fig. 6
d/	"	696 N	/26,8%	" /	-Fig. 7

Loadings,which simulated an action of a bulldozer blade were given up in discussed investigation /practically a horizontal component of force/. It was why,because this component of loading was simulated by means of a system of two horizontal parallel cords fastened to the model on the both sides and there was no possibility of determination of cord tension with a sufficient accuracy. The additional mass which created the tension in cords hung freely and was exposed to the action of uneven body forces.

Before each measurement the track was re-set in a determined which occured every 35 revolutions of a track sprocket.

The number of revolutions resulted from transmission ratio of the chain drive.

This way a constant track tension /i.e. horizontal loading

Fig. 5

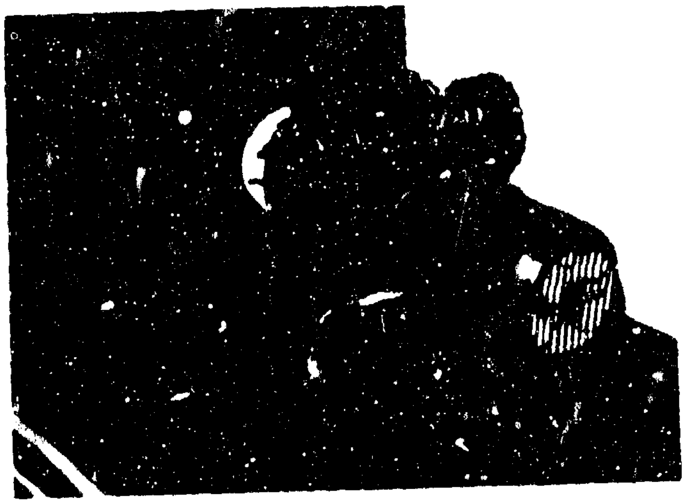


Fig. 6

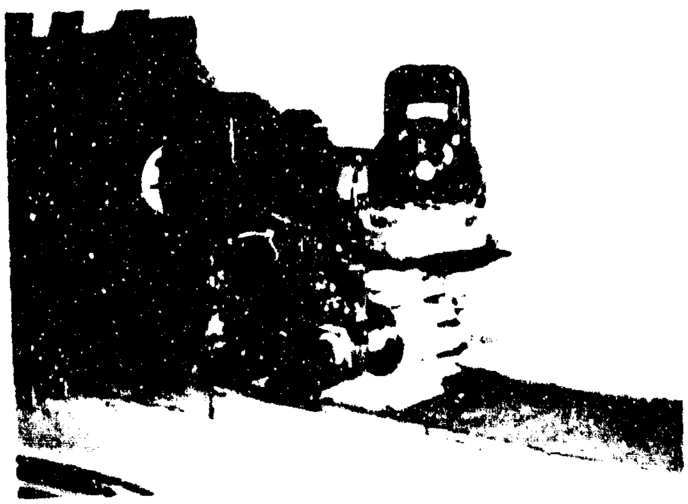


Fig. 7

the track sprocket and front wheel of the model/ was being obtained. Also each strain gauge was setting then to zero or to the constant fixed value by means of the digital voltmeter. It made sure about efficient accuracy of measurement.

DATA ANALYSIS

The conducted tests made possible to reveal some distinct regularities existing in correlations of the type of the used additional load /i.e. location of C.G./ and values of the drawbar pull as well as ground pressure distribution beneath a track of the model.

A value of the drawbar pull /D.P./ depends on a location of the centre of gravity /C.G./ The weight of the model varied, so some operations had to be introduced. When the model was loaded with an additional mass, the obtained values of D.P. were equated, so:

$$D.P._{an} = DP_m \frac{m_b}{m_m} \qquad /1/$$

where:

- $D.P._{an}$ - an analysed value of D.P.
- DP_m - a measured value of D.P.
- m_b - a basic mass of the model /265 kg/
- m_m - a mass of the model when the $D.P._m$ was measured.

The loadings of the rollers were diminished too. An influence of the additional mass was eliminated, so variable values of D.P. could have been compared.

This way a phenomenon of a change of a C.G. was obtained without changing of a total mass of the model /in theory of course/.

The displacement of C.G. influences on a point´s S location /centre of the bearing reactions of the ground/.

The point´s S location /x_S/ was computed by /?/ /fig.8/

$$x_S = \frac{/F_E - F_C/\ 0{,}25\ L + /F_{FG} - F_{AB}/\ 0{,}5\ L}{F_{AB} + F_C + F_D + F_E + F_{FG}} \qquad /2/$$

where:

$F_{AB} \ldots F_{FG}$ - reactions as shown in fig. 8

L - track ground contact length

The equation /2/ resulted from the equilibrium of moments of a bearing reactions F in relation to the point S. Such a way of computing of x_S has been admitted as a correct one, because of intentionally high value of a ratio $\frac{L_T}{L_R}$,

$$\frac{L_T}{L_R} = 4{,}25$$

where:

L_T - track link pitch

L_R - pitch of supporting rollers.

It caused the decay of vertical loading of a track between two rollers [4]. It seemed that in this case the vertical loadings were concentrated around the rollers and equation /2/ was not saddled with a significant error.

A dependence between location of C.G. and x_S was shown in fig. 9 /point D = middle of the contact area of a track/. During the investigations C.G. was shifted on a limited scale of 0,146 m /24% of the track ground contact length L/. The centre of bearing reactions S changes on a scale of 0,122 m /20% L/. D.I. value depends on the location of C.G. /x_{CG}/ as well as x_S - value.
All dependencies are non-linear; in accordance with the regression analysis /by means of the microcomputer with the plotter/ both are second-degree polynomial.

Figure 10 shows dependence $DI = f/\frac{x_{CG}}{L}/$, where x_{CG} is a displacement of C.G. measured from the location of C.G. for the model without additional mass.
In fig. 11 the course of function $DI = f/\frac{x_S}{L}/$ clearly shown that displacement of point S towards the front of the model causes an increase of D.I. to a certain degree; further displacement towards the centre of symmetry of the model /point D/ doesn't yield benefits, D.I. - value diminishes. This course of both functions $/DI = f/\frac{x_S}{L}/, DI = f/\frac{x_{CG}}{L}//$ may be explained as follows:

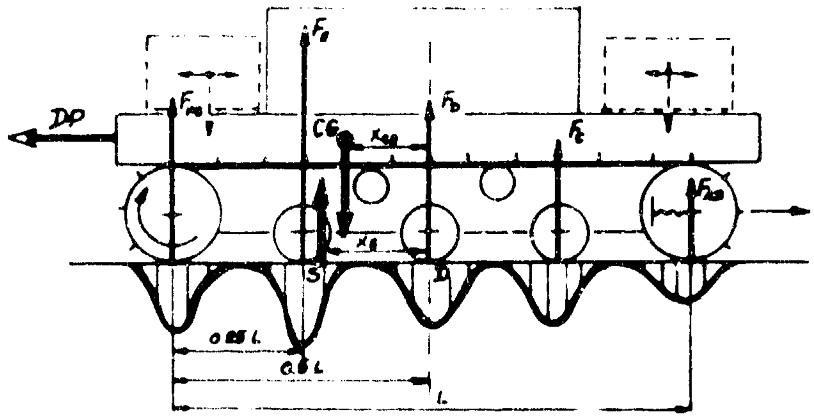


Fig. 8

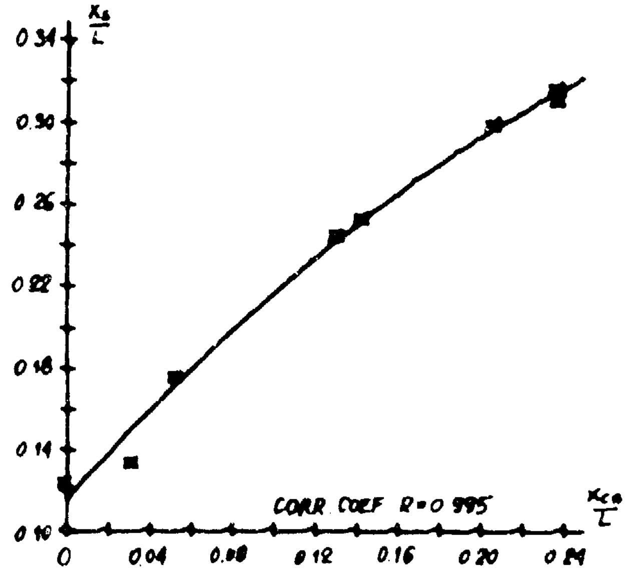


Fig. 9

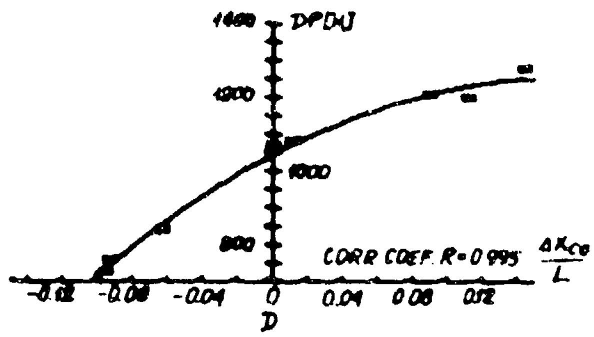

DP[N]
1400
1200
1000
800
CORR COEF R=0.995
ΔX_C0 / L
-0.12
-0.08
-0.04
0
0.04
0.08
0.12
D

Fig. 10

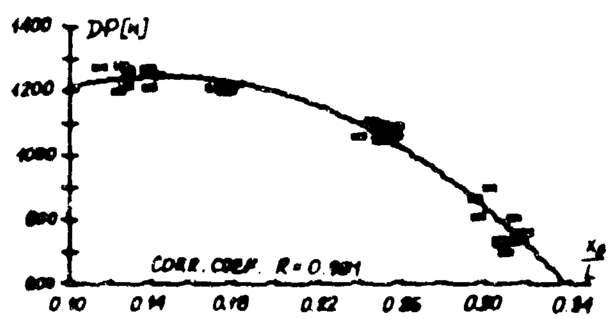
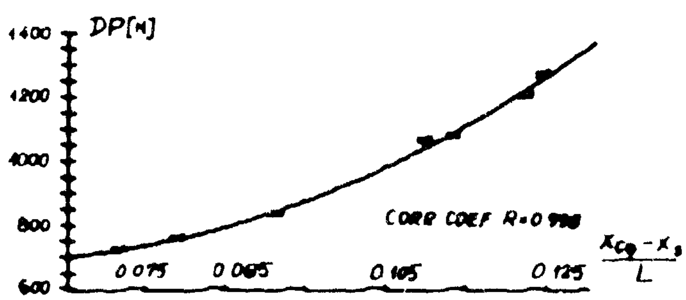

DP[N]
1400
1200
1000
800
600
CORR. COEF. R=0.981
X_s / L
0.10
0.14
0.18
0.22
0.26
0.30
0.34

Fig. 11


DP[N]
1400
1200
1000
800
600
CORR COEF R=0.998
X_C0 - X_s / L
0.075
0.085
0.105
0.125

[illegible] the model, [illegible] displacement in the [illegible] x_A [illegible]; [illegible] the model [illegible] and [illegible] hindrances.

[illegible] computed in accordance with:

$$[illegible] \int /c + p/x/ \cdot tg\phi/ \cdot /1 - \exp\frac{-j}{K}/dx \qquad /3/$$

where:

[illegible] – [illegible] of track
c – cohesion
p/x/ – normal pressure under track
ϕ – angle of internal friction
j – displacement of soil beneath a track
K – coefficient of a compression of soil

When the track ground contact length /L/ is smaller, then a value [illegible] as well as a value of force [illegible].
[illegible] /Z/ [illegible] – [illegible], where [illegible] – rolling resistance/ decrease [illegible] the hindering force F.
When the displacement of C.G. towards front of the model [illegible] of x_S and increase of D.I.
2. In accordance with [5] in the cyclically pressed ground beneath the track bearing parameters /c, ϕ/ diminish after [illegible] of the load.
In the ground loaded with pass of subsequent rollers the shear resistance [illegible] smaller. The loading of model's front [illegible] effect on increasing of D.I.
When x_S/ [illegible] the value of D.I. begins to decrease. For [illegible] $f/\frac{x_S}{L}/$ reaches 71 per cent of [illegible].
The [illegible] $f/\frac{x_{CT} - x_S}{L}/$ is shown in fig. 12.
A [illegible] D.I. versus displacement $/x_{CT} - x_S/$ [illegible] for the investigated model and given soil [illegible] coefficient of [illegible] /Z [illegible] 0,[illegible]/, therefore some conclusion can be drawn.

[illegible] distribution /x_S [illegible]/ [illegible] /fig. [illegible]/; [illegible] occurs for $\frac{x_{CG} - x_S}{L}$ = 0,055 practically when both points are in line. The larger distance between points, the higher value of D.P.

CLOSING REMARKS

1. The results of investigations confirm an assumption that D.P. depends on the location of C.G. of the model. The D.P.-value varies between 720 N and 1300 N, i.e. almost 100 per cent more.
So great difference causes a necessity of the investigation of C.G. location's effect on the drawbar pull.

2. All the obtained dependencies like D.P. versus factors of the model's state of loading are non-linear.

3. The gauges fixed in the model permitted to the continuous recording of ground reactions loaded the model's frame. Computed centre of reactions depends on the location of C.G. of a tracked vehicle.

4. The ground pressure distributions obtained during investigations permit to establish a loading spectrum of models frame and to carry out its fatigue limit analysis.

5. The carried out analysis allows to make most favourable distribution mass of the model /for the used soil/.

6. The vertical loading of the frame is not uniform as well as the triangular.
Further research on propagation of stresses in ground beneath the track /related to the concentrated force F loading a roller/ is going on.

REFERENCES

[1] A. MIERZWICKI, M. M. PONCYLIUSZ, Traction Investigation of a Track Vehicle Model, The Proceedings of the 7th Conference ISTVS, Calgary 1981

[2] N. H. COOK, E. RABINOWICZ, Physical Measurement and Analysis, Addison + Vesley, Reading 1963

[3] D. ROWLAND, Tracked Vehicle Ground Pressure and It's Effect on Soft Ground Performance, The Proceeidings of the 4th Conference ISTVS, Stockholm 1972

[4] V. SKOTNIKOV, A. PONOMAREV, A. KLIMANOV, The Mobility of the Machines /in Russian/, Minsk 1982

[5] K. KOGURE, T. KUDO, Shearing Properties of Sand Under a Repeated Loading Representing the Ground Pressure Distribution of a Tracked Vehicle, Journal of Terramechanics 1977, No 4.